Dairy beef production as an alternative to supplying the dairy company

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Dairy farmers in New Zealand are vulnerable to changes in milk payout which can be substantial. A potential option for dairy farmers is to alter their system in low payout years to dairy beef, preferentially feeding milk to the calves to achieve higher growth rates so a fodder beet wintering system can be used to finish them at under 18 months of age. High input artificial rearing, continuous milk, nurse cows and dam rearing can all achieve growth rates of ≥1 kg/d. Nurse cows were discounted for reasons of practicality and the other systems were modelled and compared to a traditional dairy replacement rearing system with all calves going into a fodder beet wintering system. Artificial rearing of calves born by 1 August with high levels of milk fed is the alternative system recommended for dairy beef as it achieves live weight targets going on to fodder beet and at slaughter.

Males finished at 553.7 kg live weight (310.0 kg carcass weight) and heifers at 497.5 kg live weight (271.0 kg carcass weight) were analysed at a range of milk and beef prices with profits per head of -$39.72 to $879.78 for males and -$215.22 to $626.28 for heifers. Artificial rearing of calves born by 1 September failed to achieve live weight targets by 1 April and then 25 December. Traditional dairy replacement rearing was the most profitable, but failed to achieve live weight targets and was used more to show how ecconomic the system for rearing replacement is compared with systems prioritising growth. Of the alternative systems dam rearing was the most profitable with profits per head of $26.77 to $1,025.02 for males and -$139.74 to $784.52 for heifers, but was not recommended on the basis of practicality and a shortage of supporting evidence. Continuous mik was the last profitable with profits per head of -$167.34 to $805.41 for males and -$342.84 to $ 551.91 for heifers. Heifers were less profitable than steers or bulls because of their lower growth rates and carcass weight percentages (54.5% vs. 56%).

Provided calves can be grown fast enough for slaughter before their second winter dairy beef can be a profitable alternative to sending milk to the dairy company at appropriate milk and beef payouts. It should be practical for farmers to adapt their systems temporarily to increase profitability.

Keywords: calf growth rates, average daily gain, milk feeding, fodder beet, economics, high input milk rearing, continuous milk, dam rearing, multiple suckling, nurse cows, replacement rearing, free contact system, natural suckling, beef finishing, milk payout, beef schedules

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Chapter 1

Introduction

In recent years New Zealand dairy farmers have experienced diverse milk prices. For Fonterra suppliers prices range from \$8.40/kg milk solids [MS] in 2013-14 to \$3.90/kg MS in 2015-16 excluding the dividend(interest.co.nz). Westland paid suppliers \$7.57/kg MS and \$3.62/kg MS and Tatua \$9.00/kg MS and \$6.41/kg MS in those seasons, ignoring retentions. Such variability in milk prices means that in some years most dairy farmers cannot make a profit from milk.

Standard dairy herd replacement rates are ~20% (Handcock, Hickson, & Back, 2015; Trafford & Trafford, 2011)which means that 80% of calves born to dairy cows will either die, be killed on-farm, bobbied or sold to dairy beef rearers. Dairy beef already has the potential to expand and utilise more of the calves produced by the dairy industry, but is made less efficient and thus less profitable by low growth rates requiring animals to be carried through a second winter before they are finished (Cook, 2014). There is evidence that there is no difference in growth potential, meat yield and quality between the main New Zealand dairy breeds (Friesian and Jersey) and beef breeds when treated the same and slaughtered at the same age and condition score (Bown, Muir, & Thomson, 2016), though Jersey is often seen as inferior due to its yellower fat.

Dairy beef may offer dairy farmers an alternative to sending milk to the dairy company when milk prices are low. Mating cows that replacements will not be kept from to beef sires could increase the weights of calves produced, for example from 36.1 kg birth weight for pure Holstein Friesian to 41.5 kg birth weight for Holstein Friesian x Hereford (Hickson, Zhang, & McNaughton, 2015). This increases the calves' potential feed intake thus increasing growth rates, and increases their mature weight so more meat is produced by the same age than for smaller breeds. Even without beef genetics, by keeping calves usually bobbied or sold to dairy beef rearers in some years and preferentially feeding the calves milk to grow them fast there may be greater profit at certain prices for milk and beef than if the milk was sent to the milk company. The aim of this study was to model how this might be achieved and at what milk and beef prices. Given industry attitudes to Jerseys only Friesian genetics were considered.

Abreviations:

Average daily gain (ADG), Live weight (LWt), Fodder beet (FB), Carcass weight (CWt), Milk solids (MS), Dry matter (DM)

Chapter 2

Literature Review

2.1 Introduction

In traditional dairy systems the majority of income and potential profit comes from sending milk to the dairy company. Rearing replacement heifers reduces the amount of milk which can be sold. Therefore the aim when rearing replacements is to develop the calf's rumen and wean it as quickly as possible(Khan, Weary, & von Keyserlingk, 2011). This means that calves are often fed less milk than they can consume in order to encourage consumption of solid feed and while target average daily gain [ADG] in live weight [LWt] may be achieved this is less than the calf's potential for growth. If sending milk to the dairy company is no longer the priority calf growth rates can be increased.

The question then becomes what is the calf's maximum growth rate and how can this be achieved. Information around rearing calves is easy to find, but not necessary relevant to the topic under review. Historically and globally there are many different systems for rearing calves. Some of these are explored with the aim of showing potential growth rates of calves in different systems. Calves are not fed solely on milk during rearing so other feeds are mentioned briefly with regards to the pre- and post-weaning period of calf rearing. Finally, the eventual purpose of this review is to aid modelling of a system for rearing dairy beef calves to go into a fodder beet [FB, *Beta vulgaris*]finishing system developed by J. Gibbs at Lincoln University (Gibbs et al., 2015; Saldias & Gibbs, 2016)so the literature around this system is explained.

2.2 Milk feeding

2.2.1 Traditional dairy calf rearing

In traditional New Zealand dairy calf rearing systems calves are separated from their mothers soon after birth and reared in sheds with milk provided to them by the farmer.The aim is to produce calves weighting a minimum of 65 kg LWtfor Friesians at weaning (DairyNZ) at approximately 10 weeks of age which means target ADGs of at least 0.5 kg/d, though ~100 kg LWt is more often used as a weaning weight (Back et al., 2016; Cardoso, Hickson, Laven, Coleman, & Back, 2015) in order to achieve the LWt target for three months of age (Table A.2) . Daily milk allowance is typically 4-5 l/hd/d,equivalent to approximately 10% of the calf's body weight (Table A.1)(Cardoso et al., 2015; DairyNZ, 2012) as it is overseas (Jasper & Weary, 2002; Khan, Lee, Lee, Kim, Kim, et al., 2007; Khan et al., 2011). Reported ADGs of Holsteins fed 4 l/d are 0.43 kg/d (Borderas, de Passille, & Rushen, 2009) and 0.54 kg/d (Huber, Silva, Campos, & Mathieu, 1984). Calf meal and straw may be offered to stimulate rumen development. This is covered later in this review. Milk is restricted both because it is more expensive than solid feeds and because high milk intakes restrict solid feed consumption (Jasper & Weary, 2002), slowing rumen development .

Over the years there has been a lot of research into how to improve this system, most frequently by increasing milk allowances for at least a short period.

2.2.2 High input artificial rearing

The term artificial rearing is used here to refer to a system where the farmer takes the milk to the calves. Most information on high milk input calf rearing focuses on the first four to six weeks of the calf's life. This is because the idea of higher milk inputs is usually to grow calves faster so they can be weaned sooner. At 6 l/d milk allowance growths rates of 0.81 kg/d (Back et al., 2016) and 0.82 kg/d (Rosenberger, Costa, Neave, von Keyserlingk, & Weary, 2016) for Holsteins were reported. ADGs of 0.73 kg/d were reported at ~9 l/d (Borderas et al., 2009), up to 1.06 kg/d at 10.1 kg/d (Sweeney, Rushen, Weary, & de Passille, 2010) and 1.0-1.1 kg/d at 12 l/d(Overest, Bergeron, Haley, & DeVries, 2016). Therefore far higher ADGs than in traditional systems are achievable.

Some studies offered milk *ad lib*. Intakes recorded include 9.47 ± 0.14 kg/d to four weeks age(Korst et al., 2017), a reported 10 kg/d and recorded 8.79 kg/d to five weeks of age(Jasper & Weary, 2002)for Holsteins. Borderas *et al.* (2009) offered Holstein calves 12 l/d and they consumed on average only 8.10 l/d until three weeks of age then 9.99 l/d to six weeks of age. Similarly, Sweeney *et al*. (2010) offered 12 kg/d, but calves only consumed 10.1 kg/d on average to six weeks of age.The absence of studies on older calves means maximum intakes when calves are older must be taken from different systems.

A recent area of research in artificial calf rearing is step-down weaning. When calves are weaned there is usually a severe growth check. ADGs as low as 0.4 kg/d, 0.36 kg/d, or even -0.21 kg/d are reported (Jasper & Weary, 2002; Roth, Barth, Gygax, & Hillmann, 2009; Sweeney et al., 2010). This is due to the abrupt transition from a diet containing milk even if other feeds are being consumed to a solely solid diet. A group in the Republic of Korea proposed a system to address this where the calves have a milk allowance of 20% of LWt for the first month then their allowance is halved for another month before they are weaned (Khan, Lee, Lee, Kim, Ki, et al., 2007). The higher feed allowance increases their growth rates then the decrease in feed allowance encourages meal consumption. Male Holstein calves on the step-down method consumed 0.15 kg/d and 1.00 kg/d of meal during the pre- and post-step periods respectively compared with 0.17 kg/d and 0.70 kg/d for the control calves kept on a milk allowance of 10% of LWt the whole time. It is theorised that the step method leading to increased solid intake stimulated rumen development as the step method calves grew better post-weaning ($P<0.05$). ADGs in the first two weeks post-weaning were 0.46 kg/d for the step down method calves and 0.36 kg/d for the controls. ADGs were also higher for female calves with 0.79 kg/d for step-down method calves and 0.58 kg/d for controls in the first 40 days post-weaning reported (Khan, Lee, Lee, Kim, Kim, et al., 2007). The effectiveness of step-down weaning is supported by Rosenberger *et al.* (2016) who used the method in a Canadian study and observed no post-weaning check. In a similar and more established method, Jasper & Weary (2002) used gradual weaning by diluting milk with water by 10% more of the total volume each day and observed no post-weaning check. The work on step-down weaning is recent and conducted in overseas systems so further research is required to confirm this weaning method would work the same in a New Zealand system, but it seems logical that it would.

2.2.3 Nurse cow rearing

Nurse cow or multiple suckling systems are where a cow is given two to four calves to feed (Moran, 2005). The calves may or may not include the cow's own calf. It is hard to find information on these systems as they are no longer widely used. The main reasons for this are the difficulties associated with getting the cow to accept the calves, and calves struggling to compete for milk so one in a set grows less. When nurse cows are used ADGs of 1.2 kg/d have been reported(Muir, Wallace, & Slay, 1995). Earlier research using lower producing cows gave gains ranging from 0.50 kg/d to 0.74 kg/d (Everitt & Phillips, 1971; Rosecrans & Hohenboken, 1982). There is also mention that nurse cows increase their milk production compared to cows milked normally, but the anoestrus period may be extended(Moran, 2005; Ryle & Orskov, 1990). This increase in milk production could make using nurse cows more efficient than traditional or artificial milk rearing systems since the cow produces more milk and the calves grow at the same or faster rates.

2.2.4 Dam rearing

Another system of calf rearing is dam rearing. Dam rearing is referred to as a free contact system, natural suckling and similar in various articles. Calves are left with their mothers so they can suckle freely while the cow is milked once or twice a day as in a traditional dairy system (Grondahl, Skancke, Mejdell, & Jansen, 2007; Johnsen et al., 2016; Khan et al., 2011; Roth et al., 2009; Veissier, Care, & Pomies, 2013). This means that the calf is fully fed and consumes more than in most artificial rearing systems. Because the calf stays with its mother public perception of welfare improves and the social interaction can also have benefits for the calf (Grondahl et al., 2007; Khan et al., 2011). The effects of dam rearing on welfare and social learning are not discussed here.

Because the calf has free access to the cow it is hard to determine how much milk it is actually consuming. There is evidence that calves can safely consume 20% of their LWt in milk per day (Khan et al., 2011).Dam reared Holstein calves could consume 6.5 ± 0.7 kg milk/d in the first week of life and 12.5 ±1.4 kg milk/d in week nine (De Passille, Marnet, Lapierre, & Rushen, 2008) though Roth *et al*. (2009) gave a figure of 15 l/d on average from birth to 13 weeks of age. This is at least twice as much as they are typically offered in traditional systems.

Due to the higher milk intake growth rates are also higher than in traditional systems. Reported values range from 0.86 kg/d (Veissier et al., 2013) to 1.4 kg/d(Johnsen et al., 2016). The age of the calves has an impact on growth rate. This is illustrated by Roth *et al*. (2009) who reported an average ADG of 1.1 kg/d in month one and 1.4 kg/d in month three for dam reared calves (Figure 1). A case study reported ADGs from 0.9-1.3 kg/d over 13 weeks (Grondahl et al., 2007). The study looked at a Norwegian dairy farm with some pasture feeding where calves stayed with their dams for 6-8 weeks then were removed and weaned. The mean ADG for the first 13 weeks was 1.2 ± 0.03 kg/d.

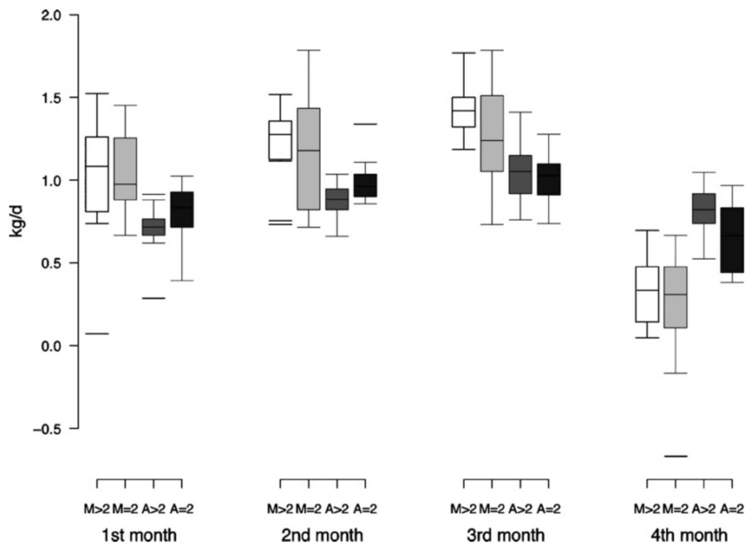

Figure 1: Growth rates for each month of calves with unrestricted (M>2) or restricted (M=2) access to their dams, or artificially fed twice (A=2) or six times (A>2) daily until abrupt weaning at the end of three months (Roth et al., 2009).

Information regarding the effect of dam rearing on calf heath are mixed. In one report using a health scoring system calves with unrestricted (31.27 ± 5.01) or restricted (35.93 ± 4.52) access to their dams for feeding had poorer scores than calves artificially fed twice (26.58 ± 3.84) or six times (23.14 ± 3.50) daily (Roth et al., 2009). However, the number of calves which received veterinary treatment was approximately 50% for all groups. Meanwhile, Grondahl *et al.* (2007) observed no health issues in calves on a Norwegian dairy farm using dam rearing. The studies report on diseases such as diarrhoea which are less of a concern in New Zealand systems than they are overseas.

While dam rearing has benefits for calf performance, health and public perception of welfare all the studies on it have been done overseas. It seems logical that increased dam rearing with the associated milk intake would improve calf performance etc in New Zealand as it does overseas, but this will not be confirmed unless New Zealand studies into the system are conducted.

2.3 Other feeds, especially post-weaning

Solid feeds are fed to calves pre-weaning primarily to stimulate rumen development so calves can utilise solid feeds post-weaning(Heinrichs, 2005). Grain (11.3 l/45.4 kg ingesta free body weight) and hay (10.6 l/45.4 kg) have both been shown to more than double reticulorumen volume at seven weeks of age compared with milk alone (4.2 l/45.4 kg) (Warner, Flatt, & Loosli, 1956). At 13 weeks volume was increased more by hay (31.4 l/45.4 kg) than by grain (13.3 l/45.4 kg). Warner, Flatt & Loosli (1956) theorised that chemical products of rumen digestion were responsible for papillae development while bulk increased volume by stretching the rumen.This is supported by a more recent review by Heinrichs (2005) reporting little or no rumen development from milk, more papillae development from diets containing casein, starch and cellulose to encourage butyrate and propionate production than from forages encouraging production of acetate, and rumen muscles and volume stimulated more by forages since they have more effective fibre and large particle sizes. This was an American review so forages are included in diets specifically for fibre so fibre content is lower quality and resists degradation more than in New Zealand pastoral systems, but the principles and need for rumen development are unchanged. Although solid feeds are important pre-weaning, the focus here is on post-weaning use of solid feeds.

2.3.1 Supplements

Supplementary feeds such as meal and grain are given to calves to increase energy or protein intake or both. This increases growth rate by providing more resources to be used for growth. As meal and grain are both used for this purpose in New Zealand they are the supplements mentioned here.

Spanning the pre- and post-weaning periods, ADGs of 0.88-1.01 kg/d were reported for meal intakes of 0.9-2.0 kg/d, with intake increasing as the calf grew (Muir, Nieuwenhuis, Smith, & Ormond, 2000). The composition of meals fed differed which could have influenced growth rates. For example the meal used by Muir *et al*. (2000) had 20% crude protein and 13.0 MJME/kg DM while the meals fed by Cardoso *et al*. (2015) were 20% crude protein until calves were within 10 kg of weaning weight, then 16% crude protein until weaning. The composition or quality of the meal affects price and how much benefit the calf gets from it.Grain is less complicated than meal in that composition is not a consideration. One study reported ADGs of 1.04 kg/d could be achieved feeding 3 kg/d of barley, though ADGs as low as 0.67 kg/d at 3 kg/d of barley offered (1.8 kg/d consumed) were also observed (Nielsen, Thamsborg, & Kristensen, 2003). An Australian study found feeding combinations of sunflower meal and oats with either hay or pasture achieved ADGs of 1.1-1.3 kg/d and up to 0.75 kg/d respectively (Dove, Freer, Axelsen, & Donnelly, 2008).

2.3.2 Crops

Crops are another option for increasing calves' energy and protein intakes especially post-weaning. In one experiment summer feeding forage brassicas ADGs of 0.90-1.25 kg/d on Winfred and 0.92-1.17 kg/d on Wairoa were reported for allowances of 3-15% of body weight (Muir et al., 1995). Summer feeding of pasture, lucerne or a mix of chicory (70%), plantain (20%) and white clover (10%) was shown to achieve ADGs of 0.53 ± 0.02 kg/d, 0.80 ± 0.02 kg/d and 0.75 ± 0.02 kg/d respectively in Friesian x Jersey heifers (Handcock et al., 2015). There are many different crops available to feed to calves, none of which are discussed in detail here.

2.3.3 Pasture

In New Zealand systems calves are given access to pasture at a few weeks old. In pastoral systems this is the logical step after they begin to consume solid feeds. A recent study reported growth rates of 0.75 kg/d in calves fed pasture pre-weaning and found no significant differences between grazing systems, though the breed of calf did have an effect (Table 1) (Back et al., 2016). This could be due to the difference in size between the breeds as the smallest breed Jersey has the lowest growth rate and the heaviest breed Friesian has the highest.This is greater than the 0.53 kg/d post-weaning reported by Handcock, Hickson & Back (2015) and may be because post-weaning growth rates tend to be lower than pre-weaning growth rates.

Table 1: Calf average daily gain [ADG] from 3-4 weeks old to weaning for different grazing treatments and breeds (Back et al., 2016).

	Days to weaning	**ADG (kg/d)**
Treatment – set stocking	91.7 ± 2.03	0.75 ± 0.032
Treatment – rotational grazing	91.2 ± 2.06	0.75 ± 0.032
Breed – Friesian	89.5 ± 2.76	0.81 ± 0.044
Breed – Jersey	91.9 ± 3.04	0.66 ± 0.047
Breed – Friesian-Jersey crossbred	92.8 ± 1.90	0.78 ± 0.030

2.4 Fodder beet wintering

New Zealand beef systems are traditionally pasture based with little or no growth over autumn and winter and finishing at 26-36 months of age (Saldias & Gibbs, 2016). Overseas systems often use cheap grain for rapid finishing so New Zealand systems with no access to this cannot compete. Gibbs developed a system where weaner beef calves are fed FB until spring (130 d) then pasture (90 d) until slaughter. The benefits of FB are high yields and utilisation, for example with yields of 20 t DM/ha and utilisations of 72.7% ± 0.1 after 24 h and 94.1% ± 0.0 after 72 h reported by Saldias & Gibbs (2016). Water soluble carbohydrates accounted for 56.4% of the bulb so FB is also a good source of energy. ADGs were 1.01 ± 0.1 kg/d on the FB and 1.2 ± 0.3 kg/d on the spring pasture. Another study on the FB phase of the same system compared growth rates of steers, heifers, and heavier and lighter animals (Gibbs et al., 2015). The heavier animals (290-370 kg on entry) had ADGs of 0.98 kg/d for steers and 0.86 kg/d for heifers while the lighter animals (240-260 kg on entry) had ADGs of 0.82 kg/d for steers and 0.81 for heifers. When wintered weaners achieved weights of 350 kg or greater by spring target slaughter weights of at least 500 kg could be achieved by 18 months of age. This evidence supports the potential of FB finishing systems to achieve target slaughter weights at least 8 months before traditional finishing systems.

2.5 Conclusions and hypothesis

In New Zealand traditional dairy calf rearing systems generally achieve ADGs of less than 0.6 kg/d. However, if the priority becomes growing the calf rather than sending milk to the dairy company higher ADGs are possible using alternative systems. High input artificial rearing can achieve ADGs from 0.73-1.1 kg/d, nurse cow rearing can achieve ADGs from 0.5-1.2 kg/d and dam rearing can achieve 0.86-1.4 kg/d. In all cases growth rates depend on the milk intake possible for a calf. Weaning methods such as the step-down method and gradual weaning can be used to decrease or avoid post-weaning checks. After weaning straight pasture feeding may only achieve ADGs of ~0.5 kg/d, but use of meal, grain or crops can increase this to ≥1.0 kg/d. The FB wintering system can maintain high growth rates over autumn and winter allowing finishing on spring pasture so slaughter weight is attained by 18 months of age.

Therefore using alternative systems such as those mentioned here it should be possible to grow calves at greater rates than are achieved in traditional dairy calf rearing systems so they are suitable to slaughter for beef by 18 months of age. Depending on prices of inputs and products this may result in a greater profit for the farmer. There is no literature around the comparable profitability of giving milk to calves in preference to sending it to the dairy company so this study aims to address this gap.

Chapter 3

Research Methods

3.1 Overview

Since the aim was to compare different systems of rearing calves either for a traditional dairy system or for the dairy beef industry, research into existing data was conducted in order to support construction of the necessary models. System models for ADGs and intake of different feeds were constructed as a basis for determining expensesand income for each of the proposed systems. Sensitivity analyses of key prices and costs were included in the financial analysis.

3.2 Research questions

3.2.1 Model specifications

The systems evaluated used Holstein Friesian dams crossed beef sires to produce calves weighing 35 kg and 30 kg for males and females respectively at birth. These birth weights as easily achievable or conservative so appropriate for use (Dhakal et al., 2013; Everitt, 1967; Hickson et al., 2015; Olson, Cassell, McAllister, & Washburn, 2009). Originally only calves born by 1 August were to be used, but as this would limit applicability for farmers in some regions of New Zealand this was extended to 1 September for three of the models.

The period until April 1 which includes milk feeding is referred to as phase 1. LWt targets are given for males unless otherwise stated and it is assumed that if males achieve LWt targets so do the females. During this phase calves need to reach a target LWtof 260 kg.All systems lead into the FB finishing system mentioned in the literature review. The period from entering the FB system until a final slaughter date of December 25 is referred to as phase 2 and is the same for all systems. The only difference from the system developed by Gibbs is that calves are transitioned directly onto FB instead of spending some time on pasture, since they are fed pasture before entering the FB system anyway. This increases the days on FB to 183. Target LWt at slaughter was 535 kg with an expected carcass weight [CWt] of approximately 300 kg which meets freezing works' preference for beef animals >270 kg CWt (J. Gibbs, personal communication). A minimum LWt of 480 kg for heifers provided an acceptable CWt of 260 kg.

3.2.2 Questions

There were two main areas where information was required:

- What alternative systems exist for rearing calves, what ADGs do these achieve and what intakes of milk and supplements are used to obtain them? How can the post-weaning check be minimised?

- What growth rates are achievable post-weaning and what feeds and intakes are necessary to obtain them?

3.3 Approach to research

To collect data for constructing the models existing literature, mostly in the form of scientific journal articles, was searched. Several papers relevant to an area of interest, for example growth rates in a high-milk input artificial rearing system,were referenced to determine a realistically achievable ADG and the amount of milk or other feed required to achieve it. Such data were then inserted into models constructed in Excel spreadsheets [Microsoft Office Excel 2007]. Sensitivity analyses of different milk prices and beef prices for both LWt and CWt were done. Excel was used for all the modelling and calculations.

3.4 Findings

3.4.1 Phase 1 – milk feeding

Information collated on ADGs and intakes for traditional and alternative calf rearing systems pre-weaning is summarised in Tables 2 and 3 and that related to post-weaning ADGs and feeding systems is summarised in Table 4. All data used in the models were checked against those in Tables 2-4 to ensure they were realistic and are also presented in the tables. Five models were developed; the traditional system using calves born by 1 September, artificial rearing using calves born by 1 August, artificial rearing using calves born by 1 September, continuous milk using calves born by 1 August and dam rearing using calves born by 1 September.

Figures for the continuous milk system were provided by Gibbs (J. Gibbs, personal communication) and seemed realistic considering information summarised in Table 3 and discussed in the literature review. While a nurse cow system was investigated, it was not continued with because the large numbers of calves, scarcity of skilled people and difficulty of achieving LWt targets (see Table A.4) was considered impractical. Milk intake in the dam rearing system was assumed to be capped at 15 l/d based on literature (Roth et al., 2009) and the fact that milking the cows would prevent the calf drinking all the milk its dam produced. As covered in the literature review many studies reported calves as drinking less than this when offered milk *ad lib*, however, these studies all used younger calves. Therefore a higher estimate from the literature was used for heavier calves. All systems modelled assumed adequate colostrum intake and that preventative animal health practices were in place.

Heifers were assumed to grow 0.1 kg/d slower than bulls or steers based on ADGs from Gibbs *et al*. (2015), though other studies reported no difference in ADG between steers and heifers (Dove et al., 2008). Comparing two similar studies by Khan *et al*. (Khan, Lee, Lee, Kim, Ki, et al., 2007; Khan, Lee, Lee, Kim, Kim, et al., 2007) shows higher ADGs of bulls than for heifers pre-weaning at 10% of body weight milk allowance (0.47 kg/d vs. 0.41 kg/d), though this was not statistically tested. ADGs were similar for bulls and heifers (0.70 kg/d vs. 0.71 kg/d) using the step-down method. Post-weaning ADGs could not be compared as they were monitored for different lengths of time.

A couple of assumptions were made regarding pasture and supplements fed. No information on pasture intakes was found in previous studies. Modelling of pasture intakes was based on recommended dry matter [DM] intakes for growing dairy heifers (DairyNZ, 2012) and consultation with T. Hughes and J. Gibbs. Another decision was to cap meal allowances at 1.5 kg/d in all except the traditional system. This was based on a study which seemed to show little increase in ADG feeding meal above 1.5 kg/d, though other treatment differences may have influenced this (Muir et al., 2000).

Table 2: A summary of feed allowancesand live weight [LWt] targets in a traditional New Zealand replacement dairy calf rearing systemaccording to industryrecommendations for Friesians and the figures used in the models based on these findings.

Topic	Reference	Age range of calves	Feed allowances and LWt targets	Figure used
Traditional system				
Milk intake	(DairyNZ, 2012)	0 – 70 d	5 l/d	5 l/d
Weaning live weight	(DairyNZ, 2012)	70 d		
	(DairyNZ)		65 kg LWt	
18 month live weight	(DairyNZ, 2012)		73% mature LWt[1]	438 kg male 401.5 kg female
Meal allowance	(DairyNZ)		2 kg/d	2 kg/d

[1] Assumed a mature LWt of 550 kg for females as for a large Holstein Friesian and 600 kg LWt for males.

Table 3: A summary of growth rates [average daily gain, ADG, kg/d] achieved and milk intakes [l/d or kg/d] allocated in previous studies using alternative calf rearing systems to the traditional New Zealand system and the growth rates and milk intakes used in the models based on these findings.

System of milk feeding	Reference	Final age of calves (d)	ADG (feed intake)	Figure used
High input artificial system	(Jasper & Weary, 2002)	35	0.8 (9)	1 (9, 12, 6)[1]
	(Korst et al., 2017)	28	0.9 (9)	
	(Overest et al., 2016)	70	1.1 (12)	
	(Sweeney et al., 2010)	41	1.0 (9)	
	(Khan, Lee, Lee, Kim, Ki, et al., 2007)	28	0.7 (max. 12)	
	(Rosenberger et al., 2016)	55	0.8 (6)	
		55	0.9 (12)	
	(Back et al., 2016)	~90	0.8 (6)	
	(Borderas et al., 2009)	42	0.7 (9)	
Nurse cow system	(Muir et al., 1995)		1.2	1.2
	(Everitt & Phillips, 1971)		0.5-0.67	
	(Moran, 2005)		0.6-0.8	
Dam rearing system	(Grondahl et al., 2007)	91	1.2	1, 1.2, 1.3[3]
	(Roth et al., 2009)	28	1	
		28-56	1.2	
		56-84	1.3	
	(Veissier et al., 2013)	70	0.86	

[1] Calves had to grow to consume maximum offered then were weaned using the step method developed by Khan *et al*. (2007).

[2] Add 25% wastage to all pasture allowances.

[3] Literature shows ADG increasing as the calf grows. Assumed ADG levelled out at 1.3 kg/d. Veissier, Care & Pomies (2013) were disregarded as their ADG was noticeably lower than in other studies, though even they report higher ADGs than in traditional calf rearing systems.

Table 4: A summary of growth rates [average daily gain, ADG] achieved and feed intakes [kg/d or kg DM/d] allocated in previous studies on post-weaning growth rates in systems similar to the New Zealand system and the growth rates used in the models based on these findings.

Reference	Age of calves (d)	Weaning method	Feed type	Feed intake	ADG (kg/d)	Figure used (kg/d)
(Handcock et al., 2015)	~180-243	-	Perennial ryegrass, white clover	-	0.53	0.8[1]
		-	Chicory, plantain, white clover	-	0.75	
		-	Lucerne	-	0.80	
(Muir et al., 1995)	~150-192	-	Wairoa forage brassica	7.9-10.0 kg DM	1.17	
		-	Winfred forage brassica	7.8-9.7 kg DM	1.25	
(Dove et al., 2008)	~180-250	-	Sunflower meal, oat or barley grain (1:1-1:4) Oat or pasture hay	3-4 kg/d *Ad lib*	1.15	
(Muir et al., 2000)	~35-84	Assume abrupt @ 35 d	Meal Pasture	1.5 kg *Ad lib*	0.75	
			Meal to 70d Meal 70-84 d Pasture 70-84 d	*Ad lib* 1.5 kg/d *Ad lib*	1.01	

[1] Confirmed as realistic by consultation with T. Hughes (personal communication).

3.4.2 Phase 2 – fodder beet finishing

As stated all the phase 1 systems lead into a FB finishing system. Figures for this system based on studies and data used in the models are given in Table 5. Data used were mostly those provided by Gibbs (J. Gibbs, personal communication) who developed the system and has been involved in most of the research into it. Although LWt at entry into the FB system does have an effect on growth rate (Gibbs et al., 2015) for simplicity this was ignored when modelling ADGs.

Table 5: A summary of growth rates and feed intakes found in a fodder beet [FB] finishing system in previous studies and the average daily gains [ADGs, kg/d] and feed intakes [kg dry matter [DM]/d] used in the models based on these findings.

Topic	Reference	Figure	Figure used
FB ADG (kg/d)	(Gibbs et al., 2015)	0.81 - 0.98 (light heifers - heavy steers)	0.9
	(Saldias & Gibbs, 2016)	1.01	
FB intake (kg DM/d)	(Gibbs et al., 2015)	Max. 9	6.5
	(Saldias & Gibbs, 2016)	Max. 8.71	
	(J. Gibbs, personal communication)	Average 6.5	
Pasture ADG (kg/d)	(Saldias & Gibbs, 2016)	1.2	1.5
	(J. Gibbs, personal communication)	1.5	
Pasture intake (kg DM/d)	(Gibbs et al., 2015)	1 with fodder beet	9[1]
	(Saldias & Gibbs, 2016)	11.23	
	(J. Gibbs, personal communication)	9[1]	

[1] Add 25% wastage to all pasture allowances.

3.4.3 Prices

Prices used were $0.85/kg meal, $0.35/kg grain, $0.10/kg DM pasture and $0.11/kg DM FB (J. Gibbs, personal communication). The $0.10/ kg DM cost for pasture assumes it is not irrigated. The effect of having irrigated pasture costing $0.20/kg DM was not modelled. Milk prices of $4, $5, $5.50 and $6/kg MS, CWt prices of $4.50, $5, $5.50, $6 and $6.50/kg CWt and store prices of $3, $3.50, $4 and $4.50/kg LWt were used for the sensitivity analyses.

Fixed costs were combined labour and animal health costs. It was assumed that land was already available so there was no additional land cost associated with rearing dairy beef calves. Labour costs were based on days of milk feeding with two hours each day required for one worker paid $25/hour to feed 100 calves. For dam rearing it was assumed no additional labour was required since the calves were fed by their mothers. After weaning it was assumed that calf rearing could be fitted in with regular dairy farm duties so there was no need for a worker specifically for the modelled systems. Animal health costs were assumed to be approximately $5/calf for all systems modelled.

3.4.4 Other assumptions

CWt was assumed to be 56% of LWt for bulls or steers and 54.5% of LWt for heifers finished in the FB system (J. Gibbs, personal communication).

When comparing profit per head with income that would have been obtained if the milk went to the dairy company rather than the calves the cost of producing the milk was not considered. Therefore the profit from each system was compared to milk income rather than profit for a traditional dairy farm system. However, the cost of milk in the systems modelled is also the price if sent to the milk company rather than the cost of producing it and the cost of production would be the same for milk going into the calf rearing systems or to the dairy company so this does not change the results of comparison only the exact figures being compared.

Chapter 4

Results

4.1 Systems modelled and their respective growth rates, live weights and feed inputs

4.1.1 Traditional replacement heifer rearing

In the traditional rearing system calves are removed from their dams soon after birth. They are fed 5 l/d of milk and increasing amounts of meal as their intake increases up to 2 kg/d. They have access to pasture at around one month of age and are weaned at about 70 days old, approximately 10 December, when they reach target LWts. In most instances they receive meal until the end of January and thereafter are solely pasture fed. Data on LWts achieved were located so growth rates were not modelled. Feed inputs for phase 1 are given in Table 6.

Table 6: Daily feed allowances and total intakes until 1 April of different feed types for a 1 September born calf in a traditional New Zealand dairy replacement rearing system.

Date	Age of calf (days)	Milk (l)	Meal (kg)	Pasture (kg dry matter [DM])	Grain (kg)
1-Sep	0	5	0.2	0	0
1-Oct	30	5	0.5	0.2	0
1-Nov	61	5	1	1	0
1-Dec	91	1.5[1]	2	2	0
1-Jan	122	0	2	3	0
1-Feb	150	0	0	4	0
1-Mar	181	0	0	4.5	0
1-Apr	212				
Total intake		**38.6**[2]	**169.5**	**557.1**	**0.0**
Final units		kgMS	kg	kgDM	kg

[1]The December milk allowance is 5 l for 9 d averaged for the month.

[2] Milk solids [MS] are 1/13 of milk.

4.1.2 Artificial rearing

In the artificial rearing systems modelled calves are born by either 1 August [August born] or 1 September [September born]. They are removed from their mothers soon after birth and fed large amounts of milk increasing up to 12 L/d as their capacity increases. Meal is offered with the amount increasing up to 1.5 kg/d as their solid feed consumption increases and pasture is also offered.

Growth rates for artificially reared August born calves are shown in Table 7 and growth rates for artificially reared September born calves are shown in Table 8. The September born calves finish about 22-25 kg LWt lighter than the August born calves because they have a month less growth.

Table 7: A model of average daily gain [ADG] and change in live weight [LWt] of male and female dairy beef calves born by 1 August and being artificially reared on high levels of milk then going into a fodder beet finishing system.

Date	Age of calf (d)	ADG (kg/d)	LWt (kg)	
			Male	Female
1-Aug	0	1	35	30
1-Sep	31	1	66	57.9
1-Oct	61	1	96	84.9
1-Nov	92	1	127	112.8
1-Dec	122	1	157	139.8
1-Jan	153	0.8	188	167.7
1-Feb	181	0.8	210.4	187.3
1-Mar	212	0.8	235.2	209
1-Apr	243	0.9	260	230.7
1-May	273	0.9	287	254.7
1-Jun	304	0.9	314.9	279.5
1-Jul	334	0.9	341.9	303.5
1-Aug	365	0.9	369.8	328.3
1-Sep	396	0.9	397.7	353.1
1-Oct	426	1.5	424.7	377.1
1-Nov	457	1.5	471.2	420.5
1-Dec	487	1.5	516.2	462.5
25-Dec	512		553.7	497.5

Table 8: A model of average daily gain [ADG] and change in live weight [LWt] of male and female dairy beef calves born by 1 September and being artificially reared on high levels of milk then going into a fodder beet finishing system.

Date	Age of calf (d)	ADG (kg/d)	LWt (kg)	
			Male	Female
1-Sep	0	1	35	30
1-Oct	30	1	65	57
1-Nov	61	1	96	84.9
1-Dec	91	1	126	111.9
1-Jan	122	1	157	139.8
1-Feb	150	0.8	185	165
1-Mar	181	0.8	209.8	186.7
1-Apr	212	0.9	234.6	208.4
1-May	242	0.9	261.6	232.4
1-Jun	273	0.9	289.5	257.2
1-Jul	303	0.9	316.5	281.2
1-Aug	334	0.9	344.4	306
1-Sep	365	0.9	372.3	330.8
1-Oct	395	1.5	399.3	354.8
1-Nov	426	1.5	445.8	398.2
1-Dec	456	1.5	490.8	440.2
25-Dec	481		528.3	475.2

Phase 1 feed intakes for artificially reared August born calves are shown in Table 9 and phase 1 feed intakes for artificially reared September born calves are shown in Table 10. The September born calves have lower total intakes for all feeds. There is barely any difference in milk consumption (1.2 kg MS), but they have noticeably lower intakes of meal (45.3 kg) and pasture (132.9 kg DM). Again, this is due to the fact they are a month younger.

Table 9: Daily feed allowances and total intakes until 1 April of different feed types for a 1 August born calf in an artificial rearing system.

Date	Age of calf (d)	Milk (l)	Meal (kg)	Pasture (kg dry matter [DM])	Grain (kg)
1-Aug	0	9	0.3	0	0
1-Sep	31	12	1.5	0.1	0
1-Oct	61	12	1.5	0.2	0
1-Nov	92	12	1.5	0.8	0
1-Dec	122	6	1.5	2	0
1-Jan	153	0	1.5	2.5	0
1-Feb	181	0	1.5	3	0
1-Mar	212	0	1.5	3.5	0
1-Apr	243				
Total		**119.8**	**327.3**	**458.4**	**0.0**
Final units		kgMS[1]	kg	kgDM	kg

[1] Milk solids [MS] are 1/13 of milk.

Table 10: Daily feed allowances and total intakes until 1 April of different feed types for a 1 September born calf in an artificial rearing system.

Date	Age of calf (d)	Milk (l)	Meal (kg)	Pasture (kgdry matter [DM])	Grain (kg)
1-Sep	0	9	0.3	0	0
1-Oct	30	12	1.5	0.1	0
1-Nov	61	12	1.5	0.2	0
1-Dec	91	12	1.5	0.8	0
1-Jan	122	6	1.5	2	0
1-Feb	150	0	1.5	2.5	0
1-Mar	181	0	1.5	3	0
1-Apr	212				
Total		**118.6**	**282.0**	**325.5**	**0.0**
Final units		kgMS[1]	kg	kgDM	kg

[1] Milk solids [MS] are 1/13 of milk.

4.1.3 Continuous milk

In the continuous milk system calves are reared as in the August born artificial system described until 1 December. From 1 December they receive a lower milk allowance than in the artificial system (4 l instead of 6 l) and from 1 January they are fed 1 kg/d of grain rather than meal. Growth rates and LWts in the continuous milk system model are shown in Table 11. The final LWts are very similar to those in the artificial August born model (Table 7). Phase 1 feed intakes for the continuous milk system are given in Table 12. Since milk feeding continues until calves enter phase 2 milk intake is greater than in the artificial August born system (22.9 kg MS difference), meal intake is lower (135 kg difference) since grain is fed instead of meal in the later part of phase 1 and pasture intake is greater (80.2 kg DM difference) since calves receive less bulk from 1 kg grain than 1.5 kg meal.

Table 11: A model of average daily gain [ADG] and change in live weight [LWt] of male and female dairy beef calves born by 1 August and being artificially reared with continuous milk then going into a fodder beet finishing system.

Date	Age of calf (d)	ADG (kg/d)	LWt (kg)	
			Male	Female
1-Aug	0	1	35	30
1-Sep	31	1	66	57.9
1-Oct	61	1	96	84.9
1-Nov	92	1	127	112.8
1-Dec	122	0.9	157	139.8
1-Jan	153	0.8	184.9	164.6
1-Feb	181	0.8	207.3	184.2
1-Mar	212	0.8	232.1	205.9
1-Apr	243	0.9	256.9	227.6
1-May	273	0.9	283.9	251.6
1-Jun	304	0.9	311.8	276.4
1-Jul	334	0.9	338.8	300.4
1-Aug	365	0.9	366.7	325.2
1-Sep	396	0.9	394.6	350
1-Oct	426	1.5	421.6	374
1-Nov	457	1.5	468.1	417.4
1-Dec	487	1.5	513.1	459.4
25-Dec	512		550.6	494.4

Table 12: Daily feed allowances and total intakes until 1 April of different feed types for a 1 August born calf in a continuous milk rearing system.

Date	Age of calf (d)	Milk (l)	Meal (kg)	Pasture (kg dry matter [DM])	Grain (kg)
1-Aug	0	9	0.3	0	0
1-Sep	31	12	1.5	0.1	0
1-Oct	61	12	1.5	0.2	0
1-Nov	92	12	1.5	0.8	0
1-Dec	122	4	1.5	2	0
1-Jan	153	4	0	2.8	1
1-Feb	181	4	0	3.7	1
1-Mar	212	4	0	4.6	1
1-Apr	243				
Total		**142.7**	**192.3**	**538.6**	**90.0**
Final units		kgMS[1]	kg	kgDM	kg

[1] Milk solids [MS] are 1/13 of milk.

4.1.4 Dam rearing

In the dam rearing system calves are left with their mothers until weaning at 1 February. The cows are milked at least once a day as in a regular dairy system.Calves have access to pasture the whole time and are fed meal after weaning. Growth rates and LWts of calves in the dam rearing model are shown in Table 13 and feed intakes for phase 1 are given in Table 14. Calves in this system consume more milk than calves in any of the other systems modelled because they have*ad lib* access to milk. This also means they have the greatest ADGs pre-weaning. They consume the least meal because they are fed it for the shortest period. Meal is not fed before weaning as the cow provides the high quality feed and would likely eat anything offered to the calf first anyway. Calves consume less pasture than in the traditional, artificial August born and continuous milk systems because they consume more milk instead.

Table 13: A model of average daily gain [ADG] and change in live weight [LWt] of male and female dairy beef calves born by 1 September and being dam reared then going into a fodder beet finishing system.

Date	Age of calf (d)	ADG (kg/d)	LWt (kg)	
			Male	Female
1-Sep	0	1	35	30
1-Oct	30	1.2	65	57
1-Nov	61	1.3	102.2	91.1
1-Dec	91	1.3	141.2	127.1
1-Jan	122	1.3	181.5	164.3
1-Feb	150	0.5	217.9	197.9
1-Mar	181	0.8	233.4	210.3
1-Apr	212	0.9	258.2	232
1-May	242	0.9	285.2	256
1-Jun	273	0.9	313.1	280.8
1-Jul	303	0.9	340.1	304.8
1-Aug	334	0.9	368	329.6
1-Sep	365	0.9	395.9	354.4
1-Oct	395	1.5	422.9	378.4
1-Nov	426	1.5	469.4	421.8
1-Dec	456	1.5	514.4	463.8
25-Dec	481		551.9	498.8

Table 14: Daily feed allowances and total intakes until 1 April of different feed types for a 1 September born calf in a dam rearing system.

Date	Age of calf (d)	Milk (l)	Meal (kg)	Pasture (kg dry matter [DM])	Grain (kg)
1-Sep	0	9	0	0.2	0
1-Oct	30	12	0	0.5	0
1-Nov	61	15	0	1	0
1-Dec	91	15	0	1.5	0
1-Jan	122	15	0	2	0
1-Feb	150	0	1.5	2.5	0
1-Mar	181	0	1.5	3	0
1-Apr	212				
Total		**152.1**	**93.0**	**405.6**	**0.0**
Final units		kgMS[1]	kg	kgDM	kg

[1] Milk solids [MS] are 1/13 of milk.

4.2 Costs and returns of the modelled systems

LWts and feed intakes allowed the costs of LWt gained by 25 December and CWt produced to be calculated. Details are shown in Table 15.

Table 15: Total intakes of different feeds, feed costs and total costs forfive different system models of dairy beef calf rearing at different milk prices ($ per kg milk solids [MS]) (phase 1) going in to a fodder beet finishing system (phase 2) and the costs per unit of live weight [LWt] gain and carcass weight [CWt] produced for steers (males) and heifers (females).

	Traditional				Artificial - August born				Artificial - September born				Continuous milk				Dam			
Milk price ($/kg MS)	**4**	**5**	**5.5**	**6.5**	**4**	**5**	**5.5**	**6.5**	**4**	**5**	**5.5**	**6.5**	**4**	**5**	**5.5**	**6.5**	**4**	**5**	**5.5**	**6.5**
Phase 1																				
Milk (kg MS)	38.60	38.60	38.60	38.60	119.80	119.80	119.80	119.80	118.60	118.60	118.60	118.60	142.70	142.70	142.70	142.70	152.10	152.10	152.10	152.10
Milk ($)	154.40	193.00	212.30	250.90	479.20	599.00	658.90	778.70	474.40	593.00	652.30	770.90	570.80	713.50	784.85	927.55	608.40	760.50	836.55	988.65
Meal (kg)	169.50	169.50	169.50	169.50	327.30	327.30	327.30	327.30	282.00	282.00	282.00	282.00	192.30	192.30	192.30	192.30	93.00	93.00	93.00	93.00
Meal ($)	144.08	144.08	144.08	144.08	278.21	278.21	278.21	278.21	239.70	239.70	239.70	239.70	163.46	163.46	163.46	163.46	79.05	79.05	79.05	79.05
Pasture (kg DM)	557.10	557.10	557.10	557.10	458.40	458.40	458.40	458.40	325.50	325.50	325.50	325.50	538.60	538.60	538.60	538.60	405.60	405.60	405.60	405.60
Pasture ($)	55.71	55.71	55.71	55.71	45.84	45.84	45.84	45.84	32.55	32.55	32.55	32.55	53.86	53.86	53.86	53.86	40.56	40.56	40.56	40.56
Grain (kg)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	90.00	90.00	90.00	90.00	0.00	0.00	0.00	0.00
Grain ($)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	31.50	31.50	31.50	31.50	0.00	0.00	0.00	0.00
Total cost	**354.19**	**392.79**	**412.09**	**450.69**	**803.25**	**923.05**	**982.95**	**1102.75**	**746.65**	**865.25**	**924.55**	**1043.15**	**819.62**	**962.32**	**1033.67**	**1176.37**	**728.01**	**880.11**	**956.16**	**1108.26**
Phase 2																				
Fodder beet (kg DM)	1189.50	1189.50	1189.50	1189.50	1189.50	1189.50	1189.50	1189.50	1189.50	1189.50	1189.50	1189.50	1189.50	1189.50	1189.50	1189.50	1189.50	1189.50	1189.50	1189.50
Fodder beet ($)	130.85	130.85	130.85	130.85	130.85	130.85	130.85	130.85	130.85	130.85	130.85	130.85	130.85	130.85	130.85	130.85	130.85	130.85	130.85	130.85
Pasture (kg DM)	1196.30	1196.30	1196.30	1196.30	1196.30	1196.30	1196.30	1196.30	1196.30	1196.30	1196.30	1196.30	1196.30	1196.30	1196.30	1196.30	1196.30	1196.30	1196.30	1196.30
Pasture ($)	119.63	119.63	119.63	119.63	119.63	119.63	119.63	119.63	119.63	119.63	119.63	119.63	119.63	119.63	119.63	119.63	119.63	119.63	119.63	119.63
Total cost	**250.48**	**250.48**	**250.48**	**250.48**	**250.48**	**250.48**	**250.48**	**250.48**	**250.48**	**250.48**	**250.48**	**250.48**	**250.48**	**250.48**	**250.48**	**250.48**	**250.48**	**250.48**	**250.48**	**250.48**
Fixed costs ($)	66.00	66.00	66.00	66.00	81.50	81.50	81.50	81.50	80.00	80.00	80.00	80.00	126.50	126.50	126.50	126.50	5.00	5.00	5.00	5.00
Final Cost	**670.66**	**709.26**	**728.56**	**767.16**	**1135.22**	**1255.02**	**1314.92**	**1434.72**	**1077.13**	**1195.73**	**1255.03**	**1373.63**	**1196.59**	**1339.29**	**1410.64**	**1553.34**	**983.49**	**1135.59**	**1211.64**	**1363.74**
Cost of production																				
Final LWt – male	438.00	438.00	438.00	438.00	553.70	553.70	553.70	553.70	528.30	528.30	528.30	528.30	550.60	550.60	550.60	550.60	551.90	551.90	551.90	551.90
$/kg LWt gain – male	1.66	1.76	1.81	1.90	2.19	2.42	2.54	2.77	2.18	2.42	2.54	2.78	2.32	2.60	2.74	3.01	1.90	2.20	2.34	2.64
Final LWt - female	401.50	401.50	401.50	401.50	497.50	497.50	497.50	497.50	475.20	475.20	475.20	475.20	494.40	494.40	494.40	494.40	498.80	498.80	498.80	498.80
$/kg LWt gain - female	1.81	1.91	1.96	2.07	2.43	2.68	2.81	3.07	2.42	2.69	2.82	3.09	2.58	2.88	3.04	3.34	2.10	2.42	2.58	2.91
CWt - male	245.00	245.00	245.00	245.00	310.00	310.00	310.00	310.00	296.00	296.00	296.00	296.00	308.00	308.00	308.00	308.00	309.00	309.00	309.00	309.00
$/kg CWt - male	2.74	2.89	2.97	3.13	3.66	4.05	4.24	4.63	3.64	4.04	4.24	4.64	3.89	4.35	4.58	5.04	3.18	3.68	3.92	4.41
CWt – female	219.00	219.00	219.00	219.00	271.00	271.00	271.00	271.00	259.00	259.00	259.00	259.00	269.00	269.00	269.00	269.00	272.00	272.00	272.00	272.00
$/kg CWt - female	3.06	3.24	3.33	3.50	4.19	4.63	4.85	5.29	4.16	4.62	4.85	5.30	4.45	4.98	5.24	5.77	3.62	4.17	4.45	5.01

The purpose of systems modelled was to produce CWt so the cheaper it was for calvesto gain LWt, the more efficient the system. For milk prices ranging from $4/kg MS to $6.50/kg MS the traditional system had the lowest cost of LWt gain ($1.66-$1.90/kg steers, $1.81-$2.07/kg heifers) followed by the dam rearing system ($1.90-$2.64/kg, $2.10-2.90/kg). LWt gain was most expensive in the continuous milk system ($2.32-3.01/kg, $2.58-3.34/kg) while costs of LWt gain in both artificial rearing systems were almost identical. Selling the animals store if they failed to reach target slaughter weight in time would also be an option. Profit per kg of LWt gained for steers and heifers at different milk and store beef prices are given in Tables 16 to 20 and 21 to 25 respectively.

Table 16: Profit ($) at different milk ($/kg milk solids [MS]) and store beef ($/kg live weight [LWt]) prices per kg of LWt gained for male dairy beef calves reared using a traditional dairy rearing system all going into a fodder beet finishing system for slaughter at 16 to 17 months of age.

		Traditional			
$/kg MS		$4.00	$5.00	$5.50	$6.50
$/kg LWt	$3.00	$1.34	$1.24	$1.19	$1.10
	$3.50	$1.84	$1.74	$1.69	$1.60
	$4.00	$2.34	$2.24	$2.19	$2.10
	$4.50	$2.84	$2.74	$2.69	$2.60

Table 17: Profit ($) at different milk ($/kg milk solids [MS]) and store beef ($/kg live weight [LWt]) prices per kg of LWt gained for August born male dairy beef calves reared using an artificial rearing system all going into a fodder beet finishing system for slaughter at 16 to 17 months of age.

		Artificial - August born			
$/kg MS		$4.00	$5.00	$5.50	$6.50
$/kg LWt	$3.00	$0.81	$0.58	$0.46	$0.23
	$3.50	$1.31	$1.08	$0.96	$0.73
	$4.00	$1.81	$1.58	$1.46	$1.23
	$4.50	$2.31	$2.08	$1.96	$1.73

Table 18: Profit ($) at different milk ($/kg milk solids [MS]) and store beef ($/kg live weight [LWt]) prices per kg of LWt gained for September born male dairy beef calves reared using an artificial rearing system all going into a fodder beet finishing system for slaughter at 16 to 17 months of age.

		Artificial - September born			
$/kg MS		$4.00	$5.00	$5.50	$6.50
$/kg LWt	$3.00	$0.82	$0.58	$0.46	$0.22
	$3.50	$1.32	$1.08	$0.96	$0.72
	$4.00	$1.82	$1.58	$1.46	$1.22
	$4.50	$2.32	$2.08	$1.96	$1.72

Table 19: Profit ($) at different milk ($/kg milk solids [MS]) and store beef ($/kg live weight [LWt]) prices per kg of LWt gained for male dairy beef calves reared using a continuous milk rearing system all going into a fodder beet finishing system for slaughter at 16 to 17 months of age.

		Continuous milk			
$/kg MS		**$4.00**	**$5.00**	**$5.50**	**$6.50**
$/kg LWt	**$3.00**	$0.68	$0.40	$0.26	-$0.01
	$3.50	$1.18	$0.90	$0.76	$0.49
	$4.00	$1.68	$1.40	$1.26	$0.99
	$4.50	$2.18	$1.90	$1.76	$1.49

Table 20: Profit ($) at different milk ($/kg milk solids [MS]) and store beef ($/kg live weight [LWt]) prices per kg of LWt gained for male dairy beef calves reared using a dam rearing system all going into a fodder beet finishing system for slaughter at 16 to 17 months of age.

		Dam			
$/kg MS		**$4.00**	**$5.00**	**$5.50**	**$6.50**
$/kg LWt	**$3.00**	$1.10	$0.80	$0.66	$0.36
	$3.50	$1.60	$1.30	$1.16	$0.86
	$4.00	$2.10	$1.80	$1.66	$1.36
	$4.50	$2.60	$2.30	$2.16	$1.86

Table 21: Profit ($) at different milk ($/kg milk solids [MS]) and store beef ($/kg live weight [LWt]) prices per kg of LWt gained for female dairy beef calves reared using a traditional dairy rearing system all going into a fodder beet finishing system for slaughter at 16 to 17 months of age.

		Traditional			
$/kg MS		**$4.00**	**$5.00**	**$5.50**	**$6.50**
$/kg LWt	**$3.00**	$1.19	$1.09	$1.04	$0.93
	$3.50	$1.69	$1.59	$1.54	$1.43
	$4.00	$2.19	$2.09	$2.04	$1.93
	$4.50	$2.69	$2.59	$2.54	$2.43

Table 22: Profit ($) at different milk ($/kg milk solids [MS]) and store beef ($/kg live weight [LWt]) prices per kg of LWt gained for August born female dairy beef calves reared using an artificial rearing system all going into a fodder beet finishing system for slaughter at 16 to 17 months of age.

		Artificial - August born			
$/kg MS		**$4.00**	**$5.00**	**$5.50**	**$6.50**
$/kg LWt	**$3.00**	$0.57	$0.32	$0.19	-$0.07
	$3.50	$1.07	$0.82	$0.69	$0.43
	$4.00	$1.57	$1.32	$1.19	$0.93
	$4.50	$2.07	$1.82	$1.69	$1.43

Table 23: Profit ($) at different milk ($/kg milk solids [MS]) and store beef ($/kg live weight [LWt]) prices per kg of LWt gained for September born female dairy beef calves reared using an artificial rearing system all going into a fodder beet finishing system for slaughter at 16 to 17 months of age.

		Artificial - September born			
$/kg MS		**$4.00**	**$5.00**	**$5.50**	**$6.50**
$/kg LWt	**$3.00**	$0.58	$0.31	$0.18	-$0.09
	$3.50	$1.08	$0.81	$0.68	$0.41
	$4.00	$1.58	$1.31	$1.18	$0.91
	$4.50	$2.08	$1.81	$1.68	$1.41

Table 24: Profit ($) at different milk ($/kg milk solids [MS]) and store beef ($/kg live weight [LWt]) prices per kg of LWt gained for female dairy beef calves reared using a continuous milk rearing system all going into a fodder beet finishing system for slaughter at 16 to 17 months of age.

		Continuous milk			
$/kg MS		**$4.00**	**$5.00**	**$5.50**	**$6.50**
$/kg LWt	**$3.00**	$0.42	$0.12	-$0.04	-$0.34
	$3.50	$0.92	$0.62	$0.46	$0.16
	$4.00	$1.42	$1.12	$0.96	$0.66
	$4.50	$1.92	$1.62	$1.46	$1.16

Table 25: Profit ($) at different milk ($/kg milk solids [MS]) and store beef ($/kg live weight [LWt]) prices per kg of LWt gained for female dairy beef calves reared using a dam rearing system all going into a fodder beet finishing system for slaughter at 16 to 17 months of age.

		Dam			
$/kg MS		**$4.00**	**$5.00**	**$5.50**	**$6.50**
$/kg LWt	**$3.00**	$0.90	$0.58	$0.42	$0.09
	$3.50	$1.40	$1.08	$0.92	$0.59
	$4.00	$1.90	$1.58	$1.42	$1.09
	$4.50	$2.40	$2.08	$1.92	$1.59

Since the purpose of modelling these systems was to find ways of reaching slaughter LWts required to meet CWt targets the lower the cost of producing CWt is the better. For cost of CWt production (Table 15) the traditional system was the cheapest per kg of CWt produced ($2.74-$3.13/kg for steers, $3.06-$3.50/kg for heifers) followed by dam rearing ($3.18-$4.41/kg, $3.62-$5.01/kg). The artificial August born ($3.66-$4.63/kg, $4.19-$5.29/kg) and artificial September born ($3.64-$4.64/kg, $4.16-$5.30/kg) rearing systems had almost identical costs. Continuous milk was the most expensive system ($3.89-$5.04/kg, $4.45-$5.77/kg). Profit per kg of CWt for steers and heifers at different milk and beef prices are given in Tables 26 to 30 and 31 to 35 respectively.

Table 26: Profit ($) at different milk ($/kg milk solids [MS]) and beef ($/kg carcass weight [CWt]) prices per kg of CWt for male dairy beef calves reared using a traditional dairy rearing system all going into a fodder beet finishing system for slaughter at 16 to 17 months of age.

		Traditional			
$/kg MS		$4.00	$5.00	$5.50	$6.50
$/kg CWt	$4.50	$1.76	$1.61	$1.53	$1.37
	$5.00	$2.26	$2.11	$2.03	$1.87
	$5.50	$2.76	$2.61	$2.53	$2.37
	$6.00	$3.26	$3.11	$3.03	$2.87
	$6.50	$3.76	$3.61	$3.53	$3.37

Table 27: Profit ($) at different milk ($/kg milk solids [MS]) and beef ($/kg carcass weight [CWt]) prices per kg of CWt for August born male dairy beef calves reared using an artificial rearing system all going into a fodder beet finishing system for slaughter at 16 to 17 months of age.

		Artificial – August born			
$/kg MS		$4.00	$5.00	$5.50	$6.50
$/kg CWt	$4.50	$0.84	$0.45	$0.26	-$0.13
	$5.00	$1.34	$0.95	$0.76	$0.37
	$5.50	$1.84	$1.45	$1.26	$0.87
	$6.00	$2.34	$1.95	$1.76	$1.37
	$6.50	$2.84	$2.45	$2.26	$1.87

Table 28: Profit ($) at different milk ($/kg milk solids [MS]) and beef ($/kg carcass weight [CWt]) prices per kg of CWt for September born male dairy beef calves reared using an artificial rearing system all going into a fodder beet finishing system for slaughter at 16 to 17 months of age.

		Artificial – September born			
$/kg MS		$4.00	$5.00	$5.50	$6.50
$/kg CWt	$4.50	$0.86	$0.46	$0.26	-$0.14
	$5.00	$1.36	$0.96	$0.76	$0.36
	$5.50	$1.86	$1.46	$1.26	$0.86
	$6.00	$2.36	$1.96	$1.76	$1.36
	$6.50	$2.86	$2.46	$2.26	$1.86

Table 29: Profit ($) at different milk ($/kg milk solids [MS]) and beef ($/kg carcass weight [CWt]) prices per kg of CWt for male dairy beef calves reared using a continuous milk rearing system all going into a fodder beet finishing system for slaughter at 16 to 17 months of age.

		Continuous milk			
	$/kg MS	$4.00	$5.00	$5.50	$6.50
$/kg CWt	$4.50	$0.61	$0.15	-$0.08	-$0.54
	$5.00	$1.11	$0.65	$0.42	-$0.04
	$5.50	$1.61	$1.15	$0.92	$0.46
	$6.00	$2.11	$1.65	$1.42	$0.96
	$6.50	$2.61	$2.15	$1.92	$1.46

Table 30: Profit ($) at different milk ($/kg milk solids [MS]) and beef ($/kg carcass weight [CWt]) prices per kg of CWt for male dairy beef calves reared using a dam rearing system all going into a fodder beet finishing system for slaughter at 16 to 17 months of age.

		Dam			
	$/kg MS	$4.00	$5.00	$5.50	$6.50
$/kg CWt	$4.50	$1.32	$0.82	$0.58	$0.09
	$5.00	$1.82	$1.32	$1.08	$0.59
	$5.50	$2.32	$1.82	$1.58	$1.09
	$6.00	$2.82	$2.32	$2.08	$1.59
	$6.50	$3.32	$2.82	$2.58	$2.09

Table 31: Profit ($) at different milk ($/kg milk solids [MS]) and beef ($/kg carcass weight [CWt]) prices per kg of CWt for female dairy beef calves reared using a traditional dairy rearing system all going into a fodder beet finishing system for slaughter at 16 to 17 months of age.

		Traditional			
	$/kg MS	$4.00	$5.00	$5.50	$6.50
$/kg CWt	$4.50	$1.44	$1.26	$1.17	$1.00
	$5.00	$1.94	$1.76	$1.67	$1.50
	$5.50	$2.44	$2.26	$2.17	$2.00
	$6.00	$2.94	$2.76	$2.67	$2.50
	$6.50	$3.44	$3.26	$3.17	$3.00

Table 32: Profit ($) at different milk ($/kg milk solids [MS]) and beef ($/kg carcass weight [CWt]) prices per kg of CWt for August born female dairy beef calves reared using an artificial rearing system all going into a fodder beet finishing system for slaughter at 16 to 17 months of age.

		Artificial - August born			
	$/kg MS	$4.00	$5.00	$5.50	$6.50
$/kg CWt	$4.50	$0.31	-$0.13	-$0.35	-$0.79
	$5.00	$0.81	$0.37	$0.15	-$0.29
	$5.50	$1.31	$0.87	$0.65	$0.21
	$6.00	$1.81	$1.37	$1.15	$0.71
	$6.50	$2.31	$1.87	$1.65	$1.21

Table 33: Profit ($) at different milk ($/kg milk solids [MS]) and beef ($/kg carcass weight [CWt]) prices per kg of CWt for September born female dairy beef calves reared using an artificial rearing system all going into a fodder beet finishing system for slaughter at 16 to 17 months of age.

		Artificial - September born			
$/kg MS		**$4.00**	**$5.00**	**$5.50**	**$6.50**
$/kg CWt	**$4.50**	$0.34	-$0.12	-$0.35	-$0.80
	$5.00	$0.84	$0.38	$0.15	-$0.30
	$5.50	$1.34	$0.88	$0.65	$0.20
	$6.00	$1.84	$1.38	$1.15	$0.70
	$6.50	$2.34	$1.88	$1.65	$1.20

Table 34: Profit ($) at different milk ($/kg milk solids [MS]) and beef ($/kg carcass weight [CWt]) prices per kg of CWt for female dairy beef calves reared using a continuous milk rearing system all going into a fodder beet finishing system for slaughter at 16 to 17 months of age.

		Continuous milk			
$/kg MS		**$4.00**	**$5.00**	**$5.50**	**$6.50**
$/kg CWt	**$4.50**	$0.05	-$0.48	-$0.74	-$1.27
	$5.00	$0.55	$0.02	-$0.24	-$0.77
	$5.50	$1.05	$0.52	$0.26	-$0.27
	$6.00	$1.55	$1.02	$0.76	$0.23
	$6.50	$2.05	$1.52	$1.26	$0.73

Table 35: Profit ($) at different milk ($/kg milk solids [MS]) and beef ($/kg carcass weight [CWt]) prices per kg of CWt for female dairy beef calves reared using a dam rearing system all going into a fodder beet finishing system for slaughter at 16 to 17 months of age.

		Dam			
$/kg MS		**$4.00**	**$5.00**	**$5.50**	**$6.50**
$/kg CWt	**$4.50**	$0.88	$0.33	$0.05	-$0.51
	$5.00	$1.38	$0.83	$0.55	-$0.01
	$5.50	$1.88	$1.33	$1.05	$0.49
	$6.00	$2.38	$1.83	$1.55	$0.99
	$6.50	$2.88	$2.33	$2.05	$1.49

In order to compare the modelled dairy beef systems with a traditional dairy system the profit per head ($/hd) was compared with the income from milk consumed in the models if it was sent to the dairy company instead. The results are shown in Tables 36 to 40 for steers and Tables 41 to 45 for heifers. The traditional system is more profitable than milk to the dairy company at any milk price modelled and any beef price except for heifers at a milk price of $6.50/kg MS with a beef price of $4.50/kg CWt. Artificial August and September born systems are more profitable at a milk price of $4/kg MS with a minimum beef price of $5.50/kg CWt or higher for steers or $6/kg CWt for heifers. The August born steers are also more profitable at a milk price of $5/kg MS with a beef price of $6/kg CWt or higher while the September born steers are also more profitable at a milk price of $5/kg MS with a minimum beef price of $6.50/kg CWt. The continuous milk system is more profitable only for steers at a milk price of $4/kg MS with a minimum beef price of $6/kg CWt. The dam rearing system is more profitable at a milk price of $4/kg MS with a minimum beef price of $5.50/kg CWt for steers and $6/kg CWt for heifers, and at a milk price of $5/kg MS with a minimum beef price of $6.50/kg CWt for steers. In some cases the difference in profitability between the modelled systems and sending the milk to the dairy company is small. For example the profitability of the artificial September born system at a milk price of $4/kg MS with a beef price of $6/kg CWt beef pricefor heifersis only $2.48 greater than sending the milk to the dairy company. Systems modelled also made losses with some combinations of milk and beef prices. For example the largest loss was -$342.84/hd which occurred in the continuous milk rearing system for heifers at a milk price of $6.50/kg MS with a beef price of $4.50/kg CWt.

Table 36: Profit ($) at different milk ($/kg milk solids [MS]) and beef ($/kg carcass weight [CWt]) prices per head for male dairy beef calves reared using a traditional dairy rearing system all going into a fodder beet finishing system for slaughter at 16 to 17 months of age compared with income that would have been obtained by sending the milk to the dairy company instead of feeding it to the calves.

		Traditional			
$/kg MS		**$4.00**	**$5.00**	**$5.50**	**$6.50**
$/kg CWt	**$4.50**	$431.84	$393.24	$373.94	$335.34
	$5.00	$554.34	$515.74	$496.44	$457.84
	$5.50	$676.84	$638.24	$618.94	$580.34
	$6.00	$799.34	$760.74	$741.44	$702.84
	$6.50	$921.84	$883.24	$863.94	$825.34
Cost of milk ($)		**$154.40**	**$193.00**	**$212.30**	**$250.90**

Table 37: Profit ($) at different milk ($/kg milk solids [MS]) and beef ($/kg carcass weight [CWt]) prices per head for August born male dairy beef calves reared using an artificial rearing system all going into a fodder beet finishing system for slaughter at 16 to 17 months of age compared with income that would have been obtained by sending the milk to the dairy company instead of feeding it to the calves.

		Artificial - August born			
$/kg MS		$4.00	$5.00	$5.50	$6.50
$/kg CWt	$4.50	$259.78	$139.98	$80.08	-$39.72
	$5.00	$414.78	$294.98	$235.08	$115.28
	$5.50	$569.78	$449.98	$390.08	$270.28
	$6.00	$724.78	$604.98	$545.08	$425.28
	$6.50	$879.78	$759.98	$700.08	$580.28
Cost of milk ($)		$479.20	$599.00	$658.90	$778.70

Table 38: Profit ($) at different milk ($/kg milk solids [MS]) and beef ($/kg carcass weight [CWt]) prices per head for September born male dairy beef calves reared using an artificial rearing system all going into a fodder beet finishing system for slaughter at 16 to 17 months of age compared with income that would have been obtained by sending the milk to the dairy company instead of feeding it to the calves.

		Artificial - September born			
$/kg MS		$4.00	$5.00	$5.50	$6.50
$/kg CWt	$4.50	$254.88	$136.28	$76.98	-$41.62
	$5.00	$402.88	$284.28	$224.98	$106.38
	$5.50	$550.88	$432.28	$372.98	$254.38
	$6.00	$698.88	$580.28	$520.98	$402.38
	$6.50	$846.88	$728.28	$668.98	$550.38
Cost of milk ($)		$474.40	$593.00	$652.30	$770.90

Table 39: Profit ($) at different milk ($/kg milk solids [MS]) and beef ($/kg carcass weight [CWt]) prices per head for male dairy beef calves reared using a continuous milk rearing system all going into a fodder beet finishing system for slaughter at 16 to 17 months of age compared with income that would have been obtained by sending the milk to the dairy company instead of feeding it to the calves.

		Continuous milk			
$/kg MS		$4.00	$5.00	$5.50	$6.50
$/kg CWt	$4.50	$189.41	$46.71	-$24.64	-$167.34
	$5.00	$343.41	$200.71	$129.36	-$13.34
	$5.50	$497.41	$354.71	$283.36	$140.66
	$6.00	$651.41	$508.71	$437.36	$294.66
	$6.50	$805.41	$662.71	$591.36	$448.66
Cost of milk ($)		$570.80	$713.50	$784.85	$927.55

Table 40: Profit ($) at different milk ($/kg milk solids [MS]) and beef ($/kg carcass weight [CWt]) prices per head for male dairy beef calves reared using a dam rearing system all going into a fodder beet finishing system for slaughter at 16 to 17 months of age compared with income that would have been obtained by sending the milk to the dairy company instead of feeding it to the calves.

		Dam			
$/kg MS		$4.00	$5.00	$5.50	$6.50
$/kg CWt	$4.50	$407.02	$254.92	$178.87	$26.77
	$5.00	$561.52	$409.42	$333.37	$181.27
	$5.50	$716.02	$563.92	$487.87	$335.77
	$6.00	$870.52	$718.42	$642.37	$490.27
	$6.50	$1,025.02	$872.92	$796.87	$644.77
Cost of milk ($)		$608.40	$760.50	$836.55	$988.65

Table 41: Profit ($) at different milk ($/kg milk solids [MS]) and beef ($/kg carcass weight [CWt]) prices per head for female dairy beef calves reared using a traditional dairy rearing system all going into a fodder beet finishing system for slaughter at 16 to 17 months of age compared with income that would have been obtained by sending the milk to the dairy company instead of feeding it to the calves.

		Traditional			
$/kg MS		$4.00	$5.00	$5.50	$6.50
$/kg CWt	$4.50	$314.84	$276.24	$256.94	$218.34
	$5.00	$424.34	$385.74	$366.44	$327.84
	$5.50	$533.84	$495.24	$475.94	$437.34
	$6.00	$643.34	$604.74	$585.44	$546.84
	$6.50	$752.84	$714.24	$694.94	$656.34
Cost of milk ($)		$154.40	$193.00	$212.30	$250.90

Table 42: Profit ($) at different milk ($/kg milk solids [MS]) and beef ($/kg carcass weight [CWt]) prices per head for August born female dairy beef calves reared using an artificial rearing system all going into a fodder beet finishing system for slaughter at 16 to 17 months of age compared with income that would have been obtained by sending the milk to the dairy company instead of feeding it to the calves.

		Artificial - August born			
$/kg MS		$4.00	$5.00	$5.50	$6.50
$/kg CWt	$4.50	$84.28	-$35.52	-$95.42	-$215.22
	$5.00	$219.78	$99.98	$40.08	-$79.72
	$5.50	$355.28	$235.48	$175.58	$55.78
	$6.00	$490.78	$370.98	$311.08	$191.28
	$6.50	$626.28	$506.48	$446.58	$326.78
Cost of milk ($)		$479.20	$599.00	$658.90	$778.70

Table 43: Profit ($) at different milk ($/kg milk solids [MS]) and beef ($/kg carcass weight [CWt]) prices per head for September born female dairy beef calves reared using an artificial rearing system all going into a fodder beet finishing system for slaughter at 16 to 17 months of age compared with income that would have been obtained by sending the milk to the dairy company instead of feeding it to the calves.

		Artificial - September born			
$/kg MS		$4.00	$5.00	$5.50	$6.50
$/kg CWt	$4.50	$88.37	-$30.23	-$89.52	-$208.13
	$5.00	$217.88	$99.28	$39.98	-$78.62
	$5.50	$347.38	$228.78	$169.48	$50.88
	$6.00	$476.88	$358.28	$298.98	$180.38
	$6.50	$606.38	$487.78	$428.48	$309.88
Cost of milk ($)		$474.40	$593.00	$652.30	$770.90

Table 44: Profit ($) at different milk ($/kg milk solids [MS]) and beef ($/kg carcass weight [CWt]) prices per head for female dairy beef calves reared using a continuous milk rearing system all going into a fodder beet finishing system for slaughter at 16 to 17 months of age compared with income that would have been obtained by sending the milk to the dairy company instead of feeding it to the calves.

		Continuous milk			
$/kg MS		$4.00	$5.00	$5.50	$6.50
$/kg CWt	$4.50	$13.91	-$128.79	-$200.14	-$342.84
	$5.00	$148.41	$5.71	-$65.64	-$208.34
	$5.50	$282.91	$140.21	$68.86	-$73.84
	$6.00	$417.41	$274.71	$203.36	$60.66
	$6.50	$551.91	$409.21	$337.86	$195.16
Cost of milk ($)		$570.80	$713.50	$784.85	$927.55

Table 45: Profit ($) at different milk ($/kg milk solids [MS]) and beef ($/kg carcass weight [CWt]) prices per head for female dairy beef calves reared using a dam rearing system all going into a fodder beet finishing system for slaughter at 16 to 17 months of age compared with income that would have been obtained by sending the milk to the dairy company instead of feeding it to the calves.

		Dam			
$/kg MS		$4.00	$5.00	$5.50	$6.50
$/kg CWt	$4.50	$240.52	$88.42	$12.37	-$139.74
	$5.00	$376.52	$224.42	$148.37	-$3.73
	$5.50	$512.52	$360.42	$284.37	$132.27
	$6.00	$648.52	$496.42	$420.37	$268.27
	$6.50	$784.52	$632.42	$556.37	$404.27
Cost of milk ($)		$608.40	$760.50	$836.55	$988.65

Chapter 5

Discussion

5.1 Dairy beef compared to traditional dairy

The results showed that dairy beef systems could be more profitable than sending milk to the dairy company within the constraints of data used in the systems modelled and the assumptions made. Traditional beef finishing systems require ADGs over 1 kg/d to be economic, but this is not achieved on pasture (Morris, 2013) and cattle are often carried through a second winter. There is no ADG over winter at even pasture allowances of 10 kg DM/100 kg LWt/d while the same allowance can achieve 1.2 kg/d in spring and 0.66 kg/d in summer (Morris, 2007). This may be due to seasonal variation in pasture quality and sward structure. The same principles apply to dairy beef systems. Finishing the animals earlier reduces costs since they do not have to be carried through a second winter (Gibbs & Saldias, 2014).The reason that dairy beef was more profitable here was that the modelled systems grew the calves to heavy enough LWts in the first autumn that the FB system could finish them by the end of December. This is supported by a study on the FB system that compared the growth of animals entering the system at LWts of 290-370kg with animals entering at 240-260 kg and found that the heavier animals left the FB at an average LWt of 423 kg for heifers and 443.4 kg for steers compared with 355.3 kg for the lighter animals (Gibbs et al., 2015).

However, there are limits to this as the sensitivity analyses showed. None of the modelled systems except the traditional replacement rearing system was more profitable than sending milk to the dairy company at a milk price of $5.50/kg MS or higher, and at lower milk prices the lowest minimum beef price any of the non-traditional modelled systems required was $5.50/kg CWt.

5.2 Differences between systems

The artificial rearing systems were not the most profitable systems modelled, but the similarity to traditional calf rearing means they are practical while achieving required high ADGs. This is supported by Sweeney *et al*. (2010) and Overest *et al*. (2016) who both achieved ADGs of ≥1 kg/d in high input artificial rearing systems as modelled. Those studies were conducted overseas in barn systems and used automatic feeders or individual pens so the system differed slightly and may not be affordable or practical for a New Zealand dairy farmer. Cardoso *et al*. (2015) and Back *et al*. (2016) managed high input artificial rearing systems in New Zealand just by increasing milk fed, but offered less than the overseas studies so calf intake would still have been limited, accounting for their lower ADGs (~0.8 kg/d).As the September born calves fall approximately 25 kg short of the target LWt for entering the FB system in reality they would likely grow slower on the FB system than was modelled(Gibbs et al., 2015). In consequence, while the models show artificial rearing of September born calves is acceptable, in reality it would likely fail to achieve the required results. Artificial rearing of August born calves is the most likely system to achieve the required ADGs and be profitable and practical.

The traditional system had the greatest profit per head and thelowest costs of production. It is also practical as it is commonly used in New Zealand. However, calves reared in the traditional system would actually have been lighter than preferred by the freezing works since they would enter the FB system about 100 kg lighter than the target LWt (see Table A.2) and would not have made up the difference. While traditional dairy rearing representan economic and practical method of calf rearing and provides a basis for comparison it is not best suited to dairy beef production.

Of the alternative rearing systems modelled dam rearing was the most profitable per head and had the lowest costs of production. It was also the only alternative system that was profitable for steers at any milk price. The issue with this system is that there are no large scale or local studies into its application. Implementing would require a large change in calf rearing practices for farmers which would likely lead to problems with performance. The Norwegian case study by Grondahl *et al.* (2007) shows it can be used, but the herd size on that farm was 15 cows and dam rearing had been used since 1999. Further research would be required before recommending this system.

The continuous milk system was the least profitable per head and had the highest costs of production. Practically it could be done since it is a variation on a traditional rearing system. However there are increased costs for feed feed and additional labour required for the extra months of milk feeding with an extended period of stress on the calf rearer. The poor profitability of this type of system was expected as milk is an expensive feed and milk feeding is usually restricted to minimize both feed and labour costs (Moran, 2005). While this system could be used, due to the lower returns and extra stress, it is not recommended.

5.3 Steers compared to heifers

Steers were more profitable than heifers. As shown steers had lower costs of LWt gain and CWt produced, and finished at higher LWts giving higher CWts. This was because steers grew more quickly (Gibbs et al., 2015) and had a higher final LWt and CWt % (J. Gibbs, personal communication). This agrees with previous findings that steers grow faster by 0.04 kg/d to ~110 d of age (Everitt, Jury, Dalton, & Ward, 1978) and achieve heavier LWts (Jury, Everitt, & Dalton, 1980)than heifers. Jury, Everitt & Dalton (1980) found steers were heavier than heifers for different breeds and at different ages. At 100 days Friesian steers weighed 103 kg and heifers weighed 96 kg while at 600 days they weighed 399 kg and 333 kg respectively. At 600 days Hereford x Friesians weighed 381 kg and 307 kg while Angus x Friesians weighed 378 kg and 311 kg for steers and heifers respectively. Some of this may be the effect of year since data for Friesians was presented for four years while the other breeds were only given for one, however it still agrees with males growing faster to heavier LWts.

5.4 Other findings

Even with the high milk intakes it was hard for the modelled systems to achieve target LWts at the end of phase 1 with only the August born artificially reared calves achieving them (260 kg LWt for males, 230.7 kg LWt for females). However, since the continuous milk (256.9 kg, 227.6 kg) and dam (258.2 kg, 232.0 kg) rearing systems had almost reached targets and did achieve minimum CWts only the September born artificial rearing system was discounted because of this. Use of earlier born calves where practicable would reduce the risk of failing to achieve final LWts or CWts.

All the models used relied on no post-weaning check in calf growth rates.As discussed in the literature review there is evidence that gradual weaning (Jasper & Weary, 2002) and step-down weaning (Khan, Lee, Lee, Kim, Ki, et al., 2007; Khan, Lee, Lee, Kim, Kim, et al., 2007; Rosenberger et al., 2016) can reduce or eliminate the post-weaning check.

5.5 Areas for further research

Grain feeding, meal composition and cropping were not looked at in much depth so further consideration of these potential system components could refine the models and possibly affect the results. Incorporating grain into systems other than the continuous milk system might reduce system costs. Meal composition can affect ADG, and although they are more complex than pasture and supplement crops might also make achieving LWt targets easier. However these factors incorporated into modified systems were not investigated. There was also little attention paid to the exact expenses involved in fixed costs or the effect of irrigated rather than dryland pasture. These expenses likely alter between different farms affecting returns. While the models allow for comparison between the proposed systems there is still considerable room for refinement.

As mentioned in the introduction, there is no evidence of differences in growth rates between dairy and beef breeds and only Holstein Friesians were modelled. The effect of different breeds is another area which could be checked.

The models in this report have also not been tested on farm to see how they perform in reality. While the growth rates and systems modelled are based on published data and evaluated for practicality where possible actual establishment and evaluation of the systems would be required to ensure nothing was overlooked which would negate or modify the predicted outcomes.

5.6 Conclusions

With appropriate milk and beef prices artificial high milk input rearing of calves born by 1 August and going into a FB finishing system seems a profitable and practical alternative to sending milk preferentially to the dairy company. Steers are more profitable than heifers, but at appropriate prices heifers can be used. Using weaning methods to avoid a post-weaning check is vital to meeting LWt targets. Therefore, at lower milk prices New Zealand dairy farmers can easily temporarily adapt their system for a different income source and increased profit.

Appendix A

Supporting Tables

A.1 Dairy industry targets and recommendations

Table A.1: : Alternative feeding systems for rearing replacement dairy calves suggested by DairyNZ (DairyNZ, 2012).

	Restricted milk	Unrestricted milk	Restricted milk and meal	Concentrated milk/high proteinmeal
Milk				
Litres per day	5	8	5	2
Days on milk	70	42	42	35
Total litres	350	336	210	70
Milk replacer (kg)	-	-	-	9
Meal (kg)	-	20	56	125
Pasture (kg DM)	28	56	28	-
Straw (bale)				1
Live weight at 10 weeks (kg)	90	110	90	100

Table A.2: Target live weights [LWt] for replacement dairy calves (DairyNZ, 2012).

		Age in months				
		3	**6**	**9**	**15**	**22**
Breed	**Mature LWt (kg)**	% of mature liveweight target				
		20%	**30%**	**40%**	**60%**	**90%**
Jersey	350	70	105	140	210	315
Jersey	400	80	120	160	240	360
J x F	450	90	135	180	270	405
Friesian	500	100	150	200	300	450
Friesian	550	110	165	220	330	495

Table A.3: Daily dry matter [DM] requirements (kg DM/head/day at 11.0 MJ ME/kg DM) for replacement dairy calves to achieve live weight [LWt] targets (DairyNZ, 2012).

Breed	**LWt gain (kg/d)**	**Age in months** (% of mature LWt)						
		3 (20%)	**6** (30%)	**9** (40%)	**15** (60%)	**18** (73%)	**21** (86%)	**22** (90%)
Jersey	0.45	2.7	3.5	4.2	5.7	6.5	7.7	8.4
J x F	0.55	3.2	4.1	5.0	6.6	7.6	9.0	9.9
Friesian	0.64	3.6	4.6	5.7	7.6	8.7	10.3	11.2

A.2 Nurse cow rearing system

Table A.4: A model of growth rates [average daily gain, ADG, kg/d] and change in live weight [LWt] of male and female calves in a nurse cow rearing system going into a fodder beet finishing system.

Date	Age of calf (d)	ADG	LWt	
			Male	Female
1-Sep	0	1.2	35	30
1-Oct	30	1.2	71	63
1-Nov	61	1.2	108.2	97.1
1-Dec	91	1.2	144.2	130.1
1-Jan	122	0.2	181.4	164.2
1-Feb	150	0.5	187	167
1-Mar	181	0.5	202.5	179.4
1-Apr	212	0.9	218	191.8
1-May	242	0.9	245	215.8
1-Jun	273	0.9	272.9	240.6
1-Jul	303	0.9	299.9	264.6
1-Aug	334	0.9	327.8	289.4
1-Sep	365	0.9	355.7	314.2
1-Oct	395	1.5	382.7	338.2
1-Nov	426	1.5	429.2	381.6
1-Dec	456	1.5	474.2	423.6
25-Dec	481		511.7	458.6

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